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(71) Applicants
The Machlett Laboratories Incorporated, 1063 Hope Street, Stamford, Connecticut, United States of America
(72) Inventors
William P. Holland, Anthony Pellergrino
(74) Agents
Reddie & Grose, 16 Theobalds Road, London WC1X 8PL

(54) X-ray tube monitor apparatus

(57) An x-ray tube with a rotating anode target 22 is provided with a detector 40 of x-rays located outside a port 36 of a housing 26 of the tube and positioned at or near a tangent line to the radiating surface 34 for observing variations in the radiation intensity due to rotation of the target, the variations being pronounced due to the heel effect of the radiation pattern. The x-ray detector can employ a scintillation material 44 and be coupled by a light guide 46 to a photodetector 48 which is removed from the path of the radiation and detects scintillations of the x-ray detector. Alternatively, the photodetector and light pipe may be replaced by a detector of germanium, silicon or an ion chamber which converts x-ray photons directly to an electric current. An electronic unit 52 determines the speed of rotation from the electric signal and can also, by fourier transform and signature analysis techniques, monitor the state of the radiating surface.

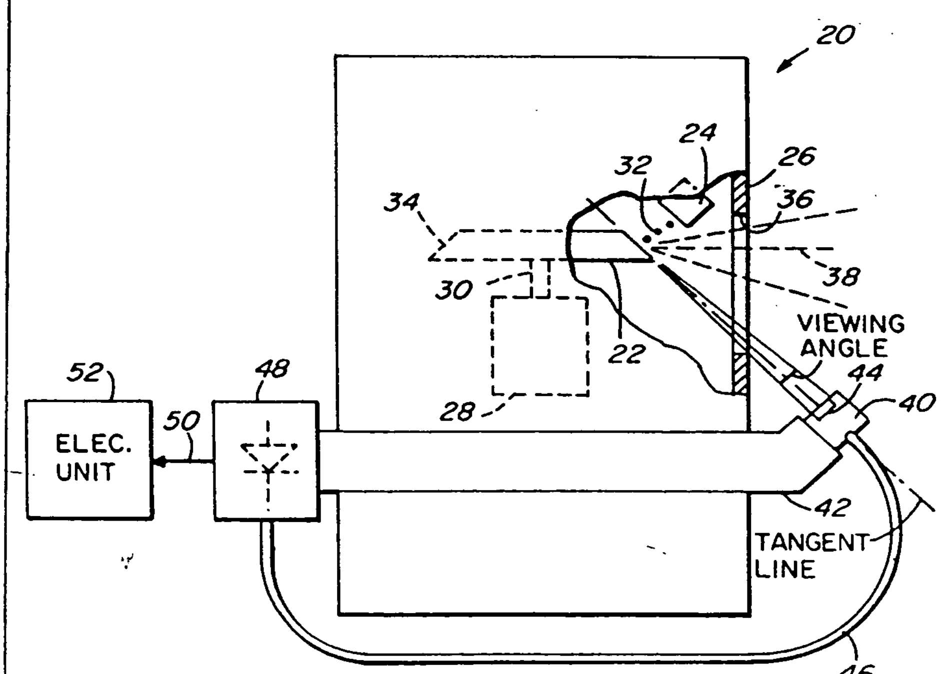

FIG. 1

GB 2 069 129 A

SPECIFICATION
X-ray tube monitor apparatus

This invention relates to rotating anode x-ray tubes and apparatus for monitoring of the speed of rotation of the anode target and the aging of the radiation surface thereof.

X-ray tubes, such as those utilized in the field of medicine for the imaging patients frequently employ a rotating anode bombarded by a beam of electrons from a cathode. The beam of electrons is directed to a focal track on an inclined surface of the anode target from which x-radiation radiates. The surface from which the radiation radiates may be referred to as the radiation surface. Rotation of the target past the electron beam distributes the heat induced by the beam along the entire focal track, thereby preventing the build up of excessive heat at any one point on the target. The distribution of the heat along the focal track allows relatively higher power densities of the x-radiation as compared to the power density attainable with a stationary target.

A problem arises in the operation of such x-ray sources in that knowledge of the speed of rotation of the target is not readily available without the use of some sort of detector of the speed of rotation. The rotation data may be utilized for determining when the power is to be increased in the anode-cathode circuit. Unfortunately, devices which measure shaft angle rotation, such as the rotation of the shaft upon which the target is mounted, require the installation of an optical, mechanical or electrically responsive device along the shaft itself which, in the case of an x-ray source, would necessitate an invasion of the housing of the source in order to install such a detection device. The application of the power is preferably delayed until the rotation of the target has attained the desired rate. In addition, the rotational data may be employed to ensure that the source is not operated at the rotational speed of a mechanical resonance of the target and the rotor of its drive motor. Also, the foregoing rotation measurement devices fail to provide any data as to the condition of the radiating surface of the target.

According to the present invention, there is provided a rotating anode x-ray tube monitor apparatus comprising the tube, x-ray detection means located to view a target of the anode along a line tangential to a radiating surface of the target, the detection means providing a signal in response to radiation incident thereon, and means coupled to the detection means for measuring a frequency of an undulation in the signal resulting from rotation of the target.

The detection means, etc. can be totally outside the housing of the x-ray tube. In one embodiment, an x-ray scintillator serves as a detector of the radiation, and is positioned adjacent the radiation exit port of the housing along a line tangent to the radiating surface of the target. The portion of the radiation propagating generally along the tangent line is often referred to as the heel effect radiation and is characterised by a substantially smaller intensity than the central portion of the radiation pattern. The placement of the x-ray detector within the heel of the radiation pattern militates against any blockage of the central portion of the x-radiation field which may be utilized, for example, for forming an image of a subject.

Placement of the x-ray detector within the path of rays of radiation lying generally along the tangent to the radiating surface to utilize the heel effect increases the sensitivity to variations in the radiation pattern resulting from rotation of the target and from aging of the target. It has been found that, even with a well balanced assembly of the target and the rotor of the motor, the rotation of the target and rotor within the housing results in a measurable perturbation of the radiation pattern. Such perturbations are believed to be due to deviations in the radiation surface from perfect symmetry about the rotor axis as well as a small misalignment of the axis of the target with the axes of the rotor and the shaft coupling the target to the rotor. Since the intensity of the radiation drops to zero or near-zero for radiant energy propagating along a tangent to the radiating surface, this being the heel effect, any of the foregoing perturbations in the alignment of the axis or of irregularities in the radiating surface provide quite large pulsations in the intensity of the radiation upon rotation of the target. The x-ray detector is preferably located to view an angle including a small region immediately above and below the tangent to the target radiating surface for sensing the foregoing pulsations of intensity in the radiation pattern, the pulsations being periodic with the rotation of the target.

The scintillations of the x-ray detector are coupled via a light pipe to a photodetector which is located at a position remote from the radiation so as to protect the photodetector, typically a semiconductor diode, from the radiation. The photodetector is coupled to an electronic unit which includes circuitry for the detection of the frequency of a pulsating electric signal produced by the photodetector in response to pulsations of the scintillations of the detector, the latter being proportional to the pulsations in intensity of the radiation in the heel of the radiation pattern. The frequency detection circuitry may take the form of an analog discriminator circuit, or a digital counting circuit which counts the interval of time over the duration of a period or a set of periods, of the target rotation.

The foregoing pulsations in the scintillations of the detector and in the corresponding electric signal of the photodetector have been found to have a generally sinusoidal type of waveform which is periodic with the period of rotation of the target. However, it is recognized that pitting or local melting of the target surface can produce a substantially step-wise discontinuity in the waveform of the photodetector signal, the step-wise discontinuity being of short duration relative to the period of rotation. Accordingly, there is provided, within a further embodiment of the

electronics unit, an electrical circuit employing a sampling of the photodetector signal by an analog-to-digital converter, the sampling being followed by a fast-fourier-transformer (FFT), a selection circuit and a signature analyser circuit. The FFT provides a set of spectral lines within a register, the lines stored within the register being periodically spaced because of the substantially constant rate of target rotation, the lines appearing at harmonic frequencies of a fundamental line due to perturbations from the substantially sinusoidal waveform associated with a smooth target. The selection circuit compares the amplitudes of the various spectral lines to obtain the line corresponding to the fundamental frequency of the spectrum, this being the frequency of rotation of the target. The signature analyzer circuit includes a memory storing a model target spectrum for a specific speed of rotation, a scaler for scaling the spectral data of the memory to conform with the actual speed of target rotation, and a correlator for correlating the scaled model spectrum with the spectrum provided by the FFT to indicate the condition of the radiating surface.

The invention will be described in more detail, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is an elevation view of an x-ray tube with a radiation detector secured to a housing thereof, a portion of the housing being cut away to show a cathode, a target, and a radiation port permitting viewing of the target along a tangent line thereto;

Figure 2 is a stylized view of the target and the port of Figure 1 superposed upon a graph of the pattern of intensity of a beam of radiation;

Figure 3 is a set of graphs of which the first two graphs show the signal of a scintillator of the detector of Figure 1 in response to a normal target and to a pitted target while the bottom two graphs show the capacitive coupling and filtering of the scintillator signal for a normal target;

Figure 4 is a block diagram of an embodiment of the electronics unit of Figure 1 employing analog circuitry in the form of a frequency discriminator, or phase locked loop, for measuring the frequency of the signals depicted in Figure 3 and, hence, the rotation of the target of Figure 1;

Figure 5 is an alternative embodiment of the electronics unit employing a limiting of the amplitude of the detector signal to provide a substantially square wave signal, and counters for counting the duration of a period of the signal;

Figure 6 is a block diagram of an alternative embodiment of the electronics unit of Figure 1 employing a fast-fourier-transformer to provide a spectral analysis of the waveforms of Figure 3 for measuring the rotational speed of the target and, via a signature analyser, a comparison of the spectrum with a reference spectrum to determine the condition of a radiating surface of the target in accordance with the invention; and

Figure 7 is a block diagram of the signature analyzer of Figure 6; and

Figure 8 is a set of graphs depicting the scaling of the spectrum as a function of the rotation of the target.

Referring now to Figure 1, there is seen an x-ray source 20 comprising a target 22 and a cathode 24 which are partially seen through a cut away portion of a housing 26 of the source 20, the remaining portion of the target 22 and the cathode 24 being shown in dotted lines. The rotor of a motor 28 is coupled via a shaft 30 to the target 22 for rotating the target 22 as a beam of electrons 32 is directed by the cathode 24 towards the radiating surface 34 of the target 22. A port 36 is provided in the side of the housing 26 adjacent the target 22 to permit the passage of a cone of x-rays 38 from the target 22.

A target monitoring system includes an x-ray detector 40 secured by an exemplary bracket 42 to the housing 26, the detector 40 being located along a tangent to the radiating surface 34 and with the port 36 being so positioned so as to provide a line of view from the detector 40 to the target 22. The detector 40 comprises scintillation material such as sodium iodide. The face 44 of the detector 40, by which the scintillation material is illuminated with the rays 38, has a cross-sectional dimension in the range of typically three millimeters to five millimeters, the face 44 subtending a relatively small viewing angle, as compared to the cone angle of the cone of radiation of the rays 38, for viewing rays 38 in the vicinity of the tangent line at the heel of the radiation pattern. Scintillations of light produced by the scintillation material in response to incident x-ray photons are coupled via an optical pipe 46, which may be a fiber optic conductor, to a photodetector 48. The photodetector 48 typically comprises a semiconductor diode for converting light in the pipe 46 to an electrical signal which is coupled via line 50 to an electronics unit 52.

Referring also to Figure 2, the graph 54 shows the intensity of the beam of x-rays 38 as a function of the polar angle between the X and the Y coordinate axes, the center of the coordinate axes being located at the point of impingement of electrons 32 upon the target 22. The edges of the beam of rays 38 are seen to be defined by the X axis, which coincides with the tangent of Figure 1, and an edge of the port 36. It is noted that for radiation directed at a relatively small angle from the X axis, the beam intensity increased rapidly as a function of angular displacement from the X axis. Thus, any angular displacement of the rotation axis 56 of the target 22 relative to the central axis of the housing 20, as may occur in the case of a mechanical resonance during the rotation of the target 22, would result in a p riodic angular offset of the tangent line of the target 22 relative to the face 44 of the detector 40 with a resultant modulation of the beam intensity as viewed by the detector 40.

While the radiation int nsity varies substantially at the heel of the pattern, the intensity of the beam is relatively constant in the mid-portion of the beam pattern so that small

perturbations in the radiating surface 22 or in its alignment relative to the housing 20 would generally have little effect on an image which would be obtained by radiating a subject and an x-ray film plate by the rays 38. It should be noted, however, that even such relatively small variations in the intensity of the mid-point of the beam pattern become noticeable in tomographic imaging systems such as, by way of example, a computerized axial tomographic (CAT) scanner.

Referring also to Figure 3, the upper graph shows a substantially sinusoidally shaped waveform of a signal provided on line 50 by the photodetector 48 in response to radiation received by the x-ray detector 40 as a function of the angular position of the target 22 about its axis 56. Variations from a true sinusoidal waveform have been exaggerated in the first graph to show the effects of perturbations in the radiating surface 34 and of misalignment of the axis 56 relative to the motor 28 in the case of a normal target. In the second graph, positive and negative perturbations have been introduced to show the effect on the intensity of radiation as viewed along the tangent in the case of the impingement upon a pitted area of the target 22 by the electrons 32.

Referring also to Figure 4, an embodiment of the electronics unit 52 of Figure 1 is portrayed, the embodiment of Figure 4 being identified by the legend 52A. The electronics unit 52A is seen to comprise a preamplifier 58 which is coupled via a capacitor 60 to an analog discriminator 62. The analog circuit of the discriminator 62 may comprise a tuned circuit of inductors and capacitors (not shown) as is well known, or a phase locked loop (PLL, not shown) which, as is well known, tracks the frequency of a periodic signal such as a sinusoid. The output signal of the discriminator 62 is applied to an indicator 64 which displays the value of the frequency, and to an exemplary switch 66 which may be utilized for applying high voltage from a power supply (not shown) to the circuit of the target 22 and cathode 24 so that the full current of the electrons 32 is not directed upon the target 22 until after the target 22 reaches its proper speed of rotation. A small electron current is applied to the target 22 initially sufficient radiation to permit measurement of the rotation. The threshold of the signal magnitude required to operate the switch 66 is sufficiently high so that the switch 66 is not operated in response to the presence of a harmonic of the fundamental frequency of rotation.

In operation, therefore, a signal on line 50 is amplified by the amplifier 58, converted by the capacitor 60 to an AC (alternating current) signal as is portrayed in the third of the graphs in Figure 3, and coupled to the discriminator 62 which provides an output voltage proportional to the fundamental frequency of the waveform of the third graph of Figure 3. Since the waveform is periodic with each increment of 360 degrees of rotation of the target 22, as is seen in the graphs of Figure 3, the fundamental frequency of the third graph of Figure 3 is therefore equal to the frequency of rotation of the target 22. Thereby, the frequency shown by the indicator 64 is the frequency of rotation of the target 22.

Referring now to Figures 3 and 5, there is presented a block diagram of another embodiment of the electronics unit 52 of Figure 1, the electronics unit of Figure 5 being identified by the legend 52B. The electronics unit 52B is seen to comprise the preamplifier 58 and the capacitor 60 which are coupled to signals on line 50, and function as described above with reference to Figure 4. The units 52B further comprises a low pass filter 68, a limiter 70, a counter 72, a flip-flop 74, a clock 76, a counter 78, a register 80 which is strobed by the flip-flop 74 via an inverter 82, a divider 84 and indicators 86 and 88. In operation, the filter 68 filters out harmonics of the signal waveform portrayed in the third graph of Figure 3 to provide a signal having the filtered waveform of the fourth graph of Figure 3. The output signal of the filter is then applied to the limiter 70 which amplifies and clips the output signal of the filter 68 to provide a substantially square wave signal 90 having a format such as that of a digital signal which may be counted by the counter 72. The counter 72 counts pulses of the signal 90 modulo-M, whereupon the counter 72 resets itself and triggers the flip-flop 74. The legend M designates the number of pulses of the signal 90 to be counted between each triggering of the flip-flop 74. In view of the correspondence between the pulses of the signal 90 and that of the sinusoidal signal at the capacitor 60 it is seen that the legend M represents the number of rotations of the target 22.

The flip-flop 74 is toggled with each trigger signal from the counter 72 to provide a square wave signal 92 which alternately enables and disables the counter 78. When enabled by the flip-flop 74, the counter 78 counts clock pulses of the clock 76. At the conclusion of the enabling period as designated by the flip-flop 74, the counter 78 strobes the register 80 to read the value of the counter 78, the contents of the register 80 being proportional to the duration of the M periods of rotation of the target 22 and, hence, being proportional to the period of rotation of the target. The indicator 86 coupled to the register 80 portrays the period of rotation of the target 22. If desired, the divider 84 may be employed for dividing unity by the period T of the register 80 to provide the reciprocal of T, the reciprocal being proportional to the frequency of rotation of the target 22. The embodiment of the electronics unit 50 of Figure 1, the embodiment of Figure 6 being identified by the legend 52C. The unit 52C is seen to comprise the preamplifier 58 coupled to the line 50, as previously described, the unit 52C further comprising an analog-to-digital converter 100, a fast-fourier-transformer 102, a clock 104, a register 106 having a graph 108 of a spectrum depicted within the block of the register 106, an address generator 110, a switch 112, shift registers 114, 115, and 116, comparators 118

and 120, a signature analyzer 122 which will be described with reference to Figure 7, a gate 124, a flip-flop 125, a register 126 and an indicator 128.

In operation, the clock 104 strobes the converter 100 to provide digital samples of the analog signal applied to the converter 100 by the preamplifier 58. The strobing rate of the converter 100 is in excess of the Nyquist rate of the harmonic frequency component of the waveform of the first graph of Figure 3 which is desired to be utilized in analyzing the signature of the waveform by the analyzer 122. For example, assuming that the target 22 is rotating at a rate of 3,000 rotations per minute (rpm) a fifth harmonic of the wave form in the first graph of Figure 3 occurs at a frequency of 15,000 rpm. A Nyquist sampling rate for reproducing that part of the wave form would be 30,000 samples per minute. Accordingly, the converter 100 would be strobed by the clock 104 at an exemplary rate of 48,000 samples per minute, this being equal to 800 samples per second.

In response to signals of the clock 104, the transformer 102 receives a set of signal samples from the converter 100 and performs a fourier transformation upon the samples, as is well known, to provide a corresponding set of digital signals of which the magnitudes represent the magnitudes of the corresponding spectral lines, and wherein the addresses of the individual signals within the set of signals represents the magnitude of the frequency. Thus, with reference to the graph 108, the addresses appear on the horizontal axis to designate a specific slot, or frequency, within the set of digital signals while the vertical axis of the graph 108 represents the magnitude of each frequency term. In the event that complex digital signals are to be utilized by the transformer 102, then, as is well known, the converter 100 may include inphase and quadrature reference signals (not shown) which are mixed with the signal from the amplifier 58, the resultant signals being converted by a pair of analog-to-digital converters (not shown) to provide inphase and quadrature digital signals of a complex digital signal.

The address generator 110, in response to pulses from the clock 104, sequentially addresses the switch 112 to select individual output lines 130 of the register 106 in order of increasing frequency, wherein each of the lines 130 corresponds to a slot of the register 106. Thereby, there appears on line 132 a succession of digital signals representing the amplitude individual ones of the spectral lines portrayed in the spectrum of the graph 108. The line 132 couples the spectral components to the shift register 114 and the comparator 118. Spectral components from the output terminal of the shift register 114 are coupled via line 133 to the analyzer 122. The input and output terminals of the register 114 are labeled A and B. The shift register 114 shifts each signal from terminal A to terminal B so that the previously addressed spectral line appears at terminal B while the presently addressed spectral line appears at terminal A. Thereby, the comparator 118 can compare the magnitude of the presently addressed spectral line with the previously addressed spectral line to determine which of the spectral lines is greater.

With reference to the graph 108, it is seen that many frequency terms in the typical spectrum are of zero value, with non-zero values appearing in the vicinity of the fundamental line and harmonics thereof. It is noted that the amplitude of the fundamental line is larger than the magnitudes of the lines along side the fundamental line. When the signal at terminal A is less than the signal at terminal B, the previous signal at terminal B represents the fundamental frequency and the present signal at terminal A is the spectral line immediately to the right of the fundamental frequency. Accordingly, when the comparator 118 detects that the signal at terminal A is less than the signal at terminal B, the comparator 118 strobes the gate 124 via flip-flop 125 to pass the address of the previous signal to line 134. The shift register 115 functions in the same manner as does the shift register 114 so that the address from the generator 110 coupled via the shift register 115 corresponds to the spectral line at terminal B of the shift register 114. Accordingly, the signal on line 134 is the frequency slot of the graph 108 corresponding to the fundamental frequency.

The shift register 116 and the comparator 120 provide the function of determining whether the target 22 is rotating at a constant speed, or whether the target 22 is still undergoing acceleration to reach its desired speed of rotation. For example, at relatively low rates of rotation, the spectrum of the graph 108 shifts to the left as the slot addresses are scaled in accordance with the speed or rotation. Thus, in the event that the target is rotating at only one-half the desired speed, the fundamental line of the spectrum 108 is found at a slot location having an address only one-half the address shown in the graph 108. The slot addresses of the harmonic frequencies are similarly scaled.

With respect to the terminals A and B of the shift register 116, the operation thereof is the same as that previously described with reference to the shift register 114 so that the frequency component at terminal B of the shift register 116 immediately precedes the next frequency component coupled by the gate 124. The flip-flop 125 is reset by the clock 104 at the beginning of each measurement interval so that the gate 124 is strobed only once during each measurement interval. For a constant value of rotation, the two frequency components have the same slot address in the graph 108 and, accordingly, the comparator 120 strobes the register 126 to read the address, or value, of the frequency component. The value of frequency in the register 126 is presented as the speed of rotation of the target 22 on the indicator 128. If desired, a read-only memory 136 and a comparator 138 may be coupled between the register 126 and the indicator 128 for providing a

further indication that the frequency of rotation is a corr ct value of rotation. The memory 136 stores one or more desired values of rotation which are then compared by the comparator 138 to the actual value of rotation as obtained from the register 126 for signaling the indicator 128 to display that the rate of rotation is correct.

Referring now to Figure 7, the signature analyzer 122 of Figure 6 is seen to comprise an address generator 140, a selector switch 142, a memory 144, a scaler 146, a programmer 148, a memory 150, a correlator 152 and a display 154. One input terminal of the switch 142 is coupled via line 156 to the shift register 115 of Figure 6, and an input terminal of the memory 144 is coupled via the line 133 to the shift register 114 of Figure 6.

Referring also to Figure 8, the analyzer 122 of Figure 7 is seen to operate as follows. The programmer 148, in response to clock pulses at terminal C from the clock 104 of Figure 6 operates both the switch 142 and the scaler 146. The slot address on line 156 is initially coupled via the switch 142 for addressing the memory 144 for storing data of the spectrum stored in the register 106 and portrayed in the graph 108 of Figure 6. The spectral data is coupled from the register 106, via the switch 112, the shift register 114, and the line 133 to the memory 144. Since the address on line 156 corresponds to the frequency component on line 133, the memory 144 stores the same data found in the register 106. After all the data of the register 106 has been read into the memory 144, the programmer 148 directs the switch 142 to the address generator 140 for reading the data out of the memory 144 into the correlator 152. In addition, the address of the generator 144 is applied via a scaler 146 to the memory 150 for reading out data from the memory 150 into the correlator 152. The memory 150 is a read-only memory for storing the spectral lines of an exemplary spectrum of the rotation of a target such as the target 22.

It is noted that the spectrum of the target rotation is a function of the speed of rotation. As shown in the three graphs of Figure 8, the spectrum is compressed towards the left for relatively slow values of rotation, the spacings between the spectral lines becoming expanded for faster values of rotation. Accordingly, in order to correlate the exemplary spectrum of the memory 150 with the measured spectrum of the memory 144, the locations of the frequency components, as designated by the slot address in the graph 108 of Figure 6, need be scaled to compensate for the rate of rotation of the target 22 as has been explained with reference to Figure 8. Accordingly, the programmer 148 introduces scale factors into the scaler 146 for scaling the slot addresses of the exemplary spectrum. For each scale factor, a new correlation is performed by the correlator 152. The best value of the correlation, this corresponding to the best match between the exemplary spectrum and the measured spectrum, is presented on the display 154. Thereby, the analyzer 122 presents a comparison of the measured spectrum with an exemplary spectrum whereby an operator of the source 20 of Figure 1 can determine that the source 20 is functioning properly.

CLAIMS

1. A rotating anode x-ray tube monitor apparatus comprising the tube, x-ray detection means located to view a target of the anode along a line tangential to a radiating surface of the target, the detection means providing a signal in response to radiation incident thereon, and means coupled to the detection means for measuring a frequency of an undulation in the signal resulting from rotation of the target.

2. Apparatus according to claim 1, wherein the detection means is positioned outside an x-ray transmitting port of a housing of the tube.

3. Apparatus according to claim 2, wherein the detection means includes a scintillator, means for converting scintillations of the scintillator into the said signal, and means isolating the converting means from radiation emanating from the target.

4. Apparatus according to claim 3, wherein the isolating means includes a light conduit for coupling scintillations to the converting means, the converting means being positioned at a distance from the x-ray transmitting port.

5. Apparatus according to any of claims 1 to 4, wherein the measuring means includes a frequency discriminator responsive to the signal for providing a measure of the frequency.

6. Apparatus according to claim 5, wherein the measuring means further includes switching means activated by the discriminator for controlling the power applied between the cathode and anode of the tube.

7. Apparatus according to any of claims 1 to 4, wherein the measuring means includes means for counting clock signals during a predetermined number of periods of the said undulations to determine the duration of one of those periods.

8. Apparatus according to any of claims 1 to 4, wherein the measuring means includes a fourier transformer for providing a spectrum of the signal, and means for selecting the fundamental frequency of the spectrum.

9. Apparatus according to claim 8, wherein the measuring means further includes means responsive to the spectrum for analyzing the signature of the spectrum.

10. Apparatus according to claim 9, wherein the signature analyzer includes a memory for storing a reference spectrum and means for correlating the first mentioned spectrum with the reference spectrum.

11. Apparatus according to claim 10, wherein the signature analyzer further comprises a memory for storing the first mentioned spectrum, and means coupled to one of the memories for scaling an address thereto to equalize the scale of the first mentioned spectrum with the scale of the reference spectrum, thereby compensating for the speed of rotation of the target.

12. A radiation monitor for a source of radiation

having a rotatable target, comprising means for sighting along a radiating surface of the target, the sighting means including means responsive to the radiation for signaling the presence of the radiation; means coupled to the sighting means, and shielded from the radiation for providing an electrical signal proportional to the intensity of the radiation; and means for measuring a frequency component of the signal equal to a rate of rotation of the target.

13. A radiation monitor for a source of radiation having a rotatable target, comprising means, aligned with a tangent to a radiating surface of the target, for viewing radiation emitted generally in a direction of the tangent, the viewing means being located externally to a housing of the source; and means coupled to the viewing means and responsive to variations in the intensity of the radiation as viewed by the viewing means for measuring a frequency component thereof equal to the speed of rotation of the target.

14. A radiation monitor for a source of radiation having a rotatable target, comprising means, aligned with a tangent to a radiating surface of the target, for viewing radiation emitted generally in a direction of the tangent, the viewing means being located externally to a housing of the source; and means coupled to the viewing means and responsive to variations in the intensity of the radiation as viewed by the viewing means for analyzing the surface conditions of the target.

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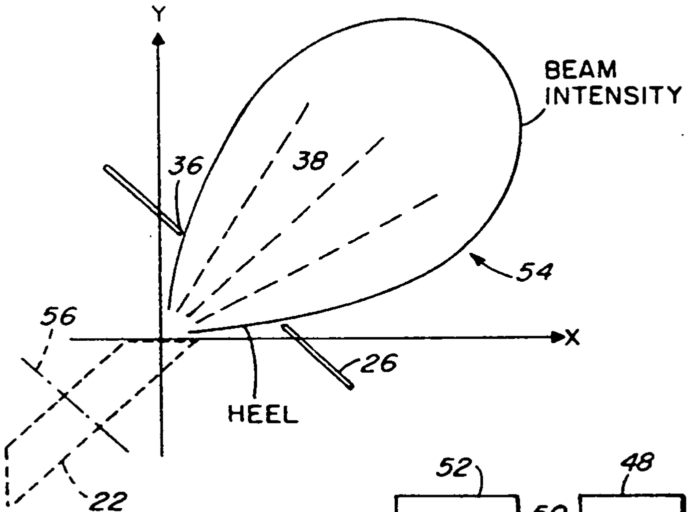


FIG. 2A

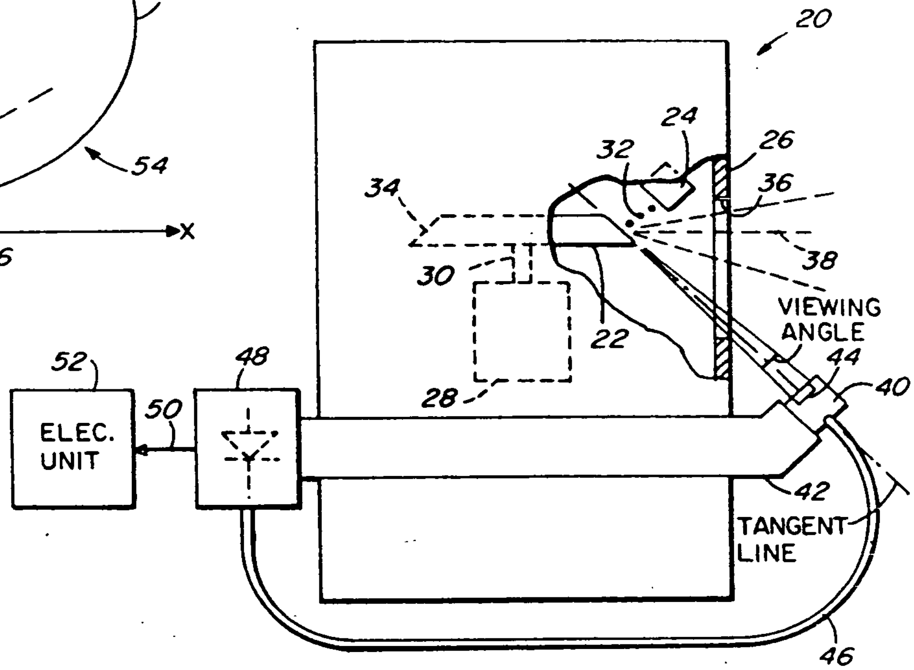


FIG. 1

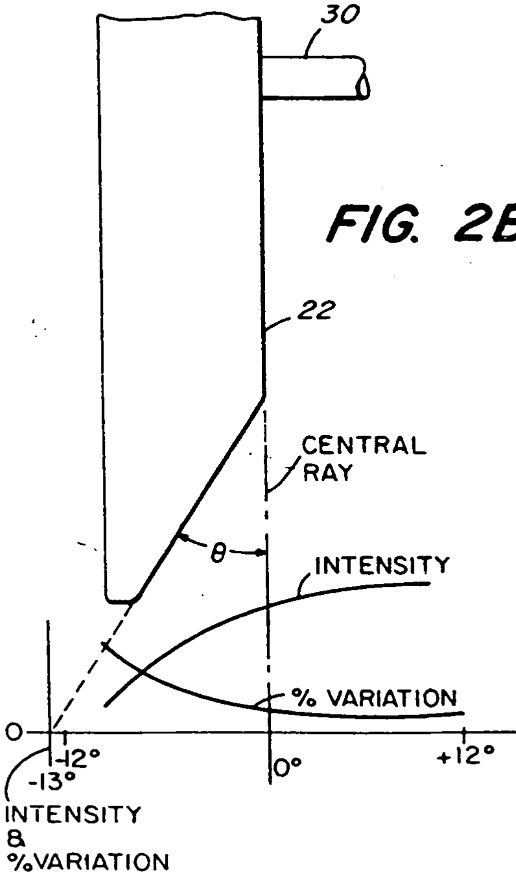
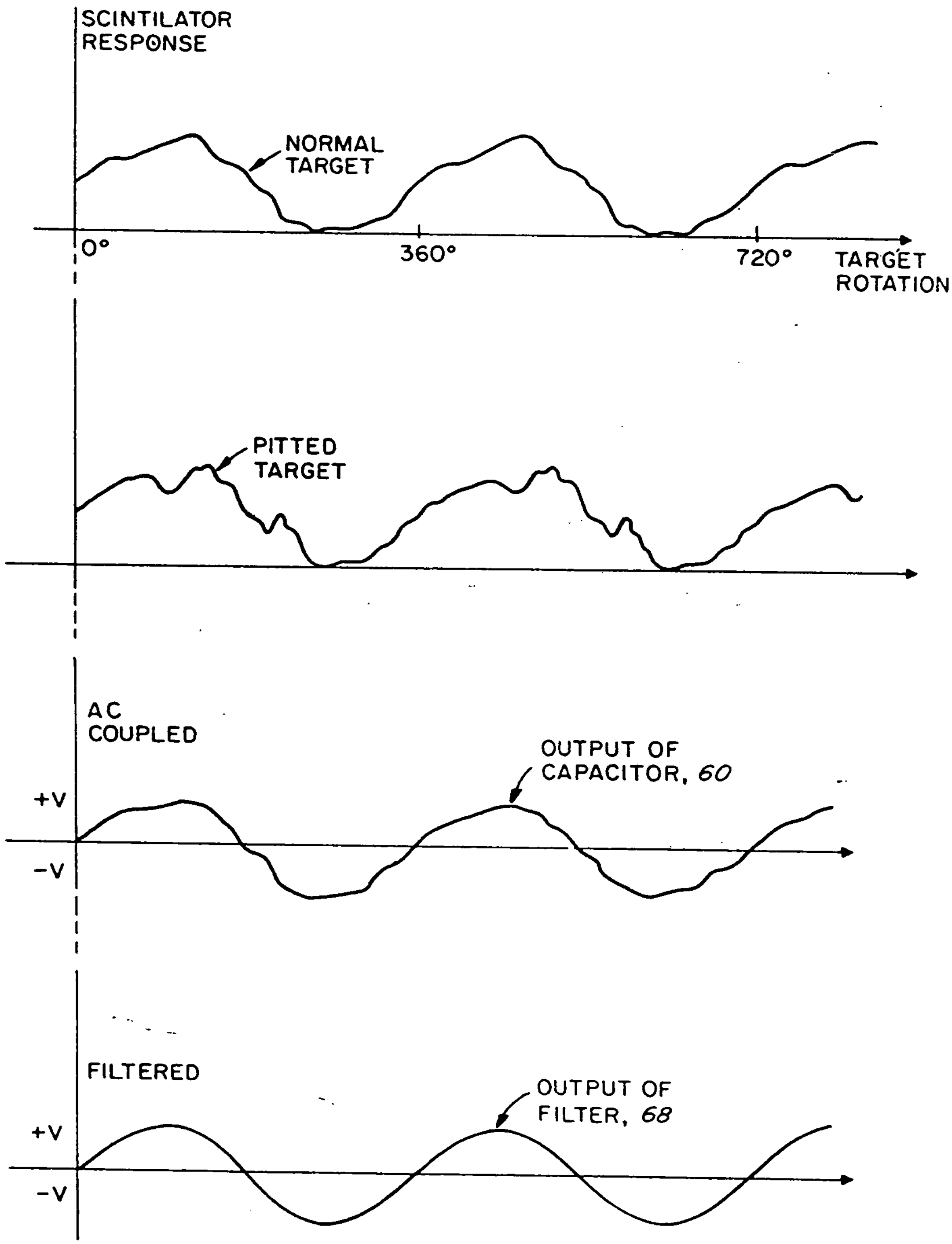


FIG. 2B

θ DEG.	% INT.	% VAR.
+10	110	0.5
0	100	1.5
−10	38	36

FIG. 2C


SCINTILATOR
RESPONSE
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TARGET
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360°
720°
TARGET
ROTATION
PITTED
TARGET
AC
COUPLED
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CAPACITOR, 60
+V
-V
FILTERED
OUTPUT OF
FILTER, 68
+V
-V

FIG. 3

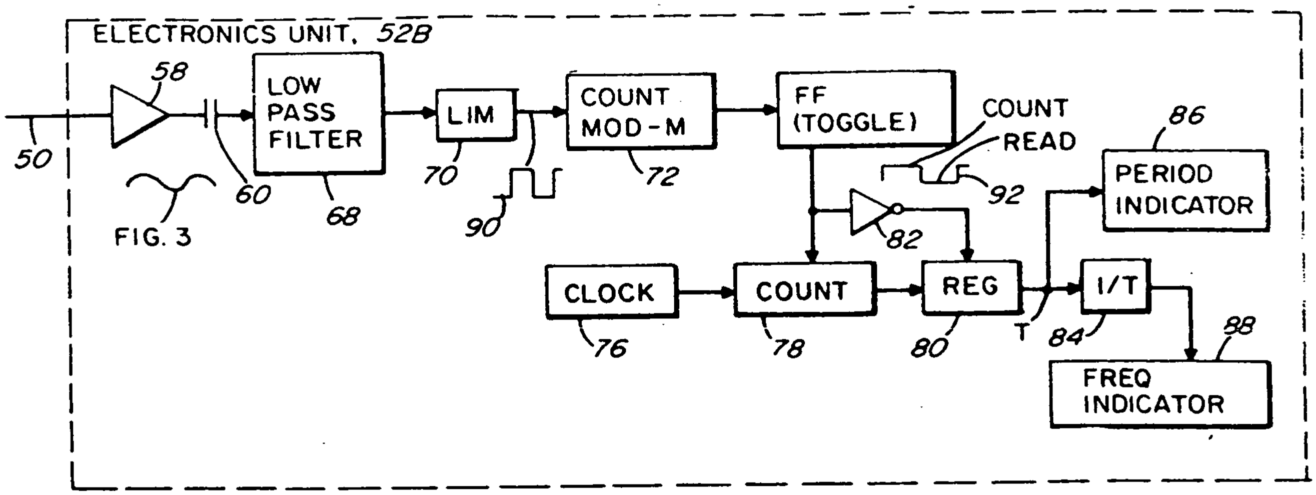


FIG. 5

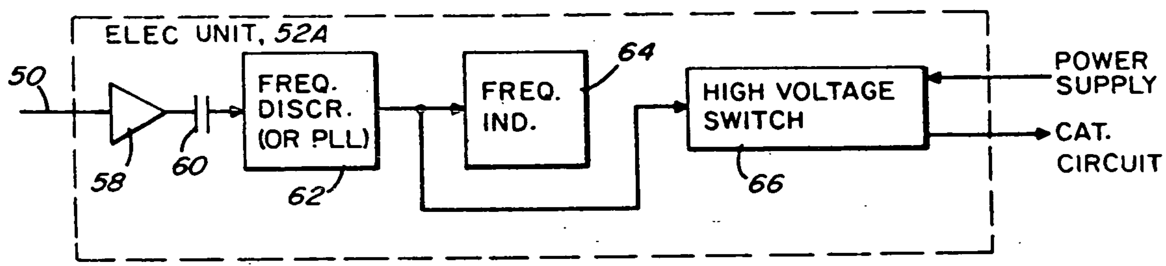
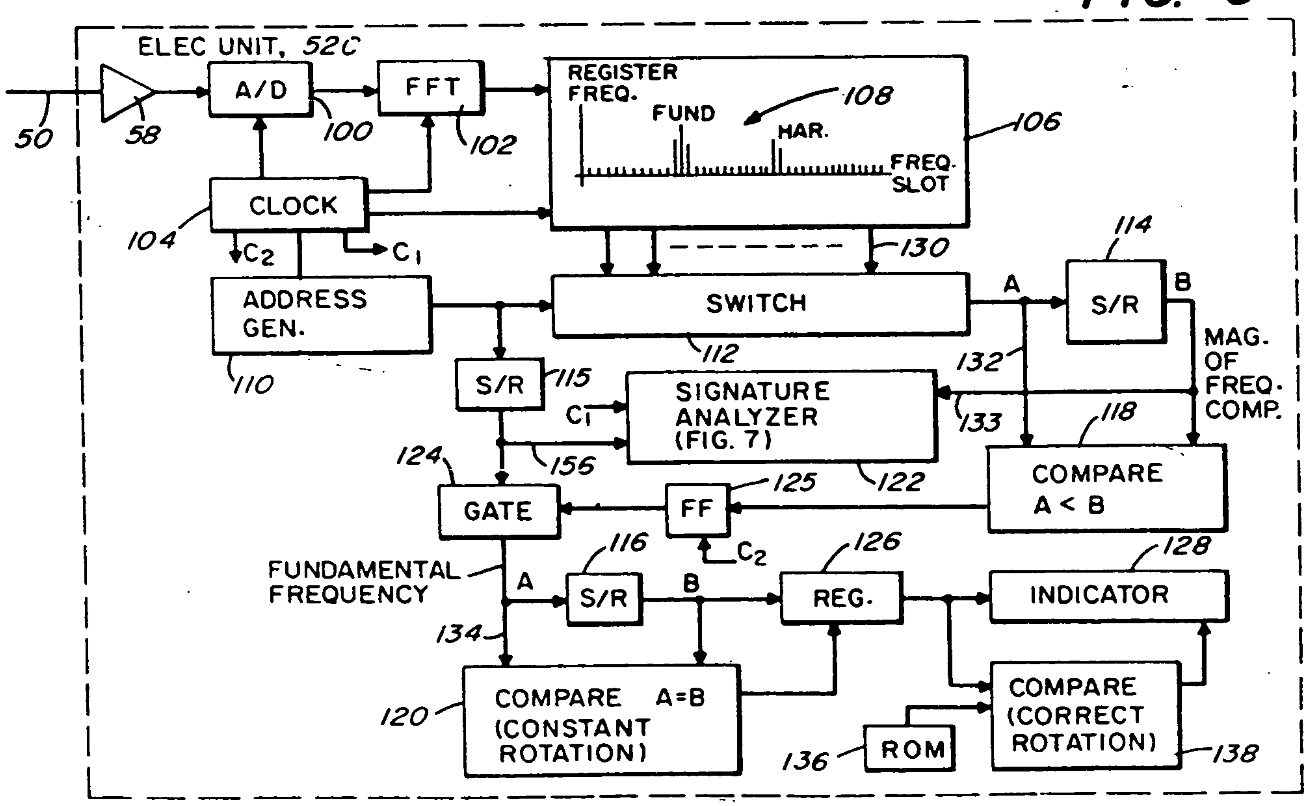
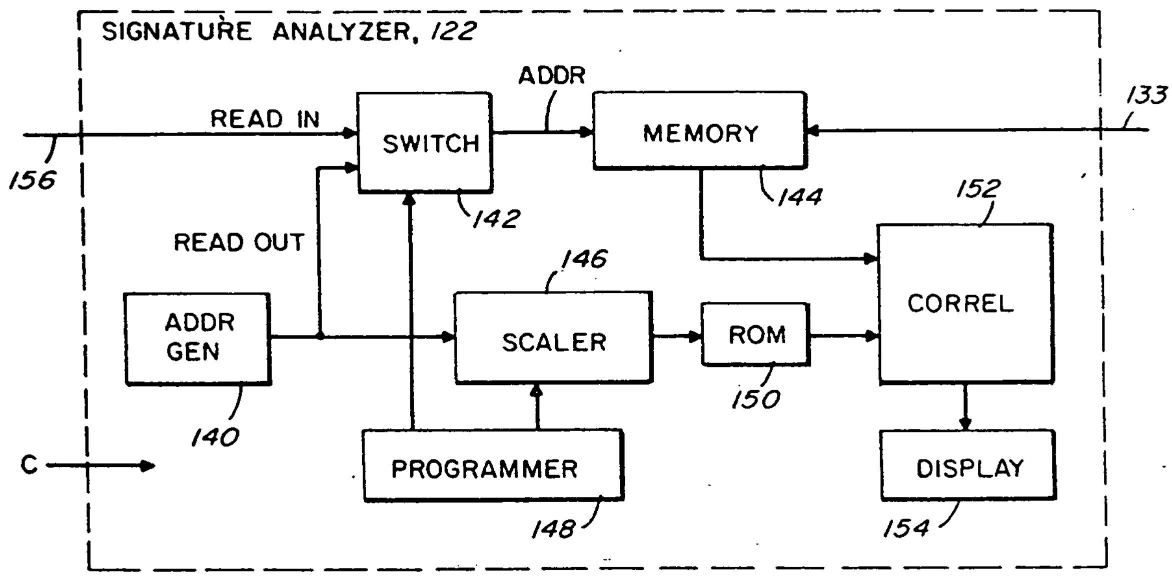


FIG. 4

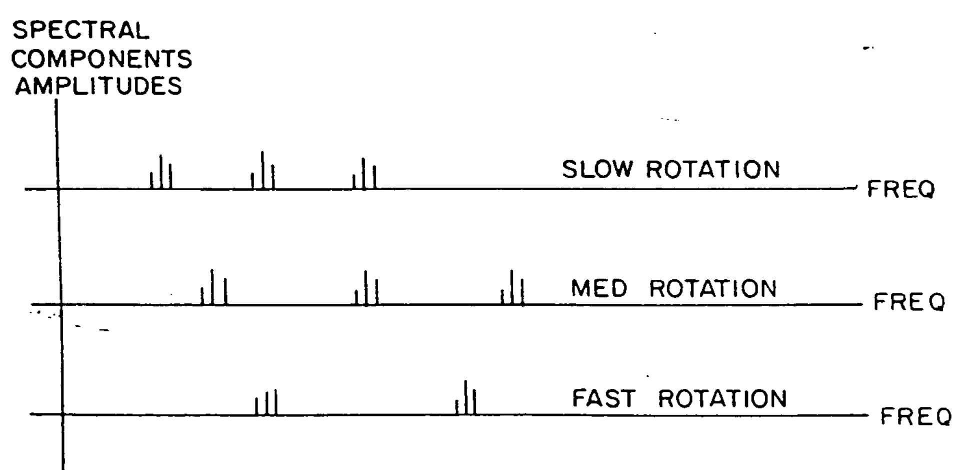
FIG. 6





SIGNATURE ANALYZER, 122
READ IN
ADDR
SWITCH
MEMORY
133
156
142
144
152
READ OUT
146
ADDR GEN
SCALER
ROM
CORREL
140
150
C
PROGRAMMER
DISPLAY
148
154

FIG. 7



SPECTRAL COMPONENTS AMPLITUDES
SLOW ROTATION
FREQ
MED ROTATION
FREQ
FAST ROTATION
FREQ

FIG. 8